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Understanding emotional responses and perception within new creative practices of biological materials

Nurul 'Ayn Ahmad Sayuti[12], Saeema Ahmed-Kristensen[1]

[1]School of Design, Royal College of Art, London, United Kingdom
[2]Industrial Design Department, Faculty of Art & Design, Universiti Teknologi MARA, Malaysia

Abstract: There is an increasing trend for designers to use living systems, through biodesign and biophilia in the urban environment. As new creative processes emerge, the perception and emotional responses of users towards these new systems are somewhat unknown. This paper aims to study the emotional responses and perceptions towards biological materials that are embedded in existing product designs. Data was collected from 58 respondents through an online questionnaire. The findings from this exploratory study show that the significant differences by comparing the respondents with a background in design and non-design towards the level of desirability, practicality, aesthetically pleasing and the common use towards artificial and real biological materials. This paper extends existing understanding of perception and emotional responses to design incorporated living systems and can begin validating existing studies which have brought different perspectives towards the functions, practicality, aesthetical value and emotional attachments of products.

Keywords*: biophilic design, biodesign, biological materials, emotional design, product design*

1. Introduction

With the emergence of new biological materials in everyday designs, the perception of the products' functions, practicality, aesthetical value and emotional attachments formed are unknown. Design genre such as biophilic design, biodesign, bio-inspired design, biomimicry amongst other are growing areas encouraging the usage of biological materials. These are not only motivated to solve problems such as environmental impact but also expand the use of biological materials to the next level in product design development. The use of living biological elements are no longer restricted to the scientific field, but it has gone beyond to engineering and design with the incorporation of these living materials into the structures, objects and processes (Myers, 2018). The examples are circumventive organs by Agi Haines, Bioencryption, modified bacteria (Escherichia coli) encryption methods by School of Life sciences, Hong Kong and Lung-on-a-chip, microfluidic channels etched into a transparent polymer, human alveolus and endothelial cells by Donald E. Ingber and Dongeun Huh (Myers, 2018). Designers and scientists are eager to explore to produce and use more radical materials extending the norm of the everyday products used to be. This transition in the design field can no longer be ignored as the diversity of these cross fields encourage a more radical approach in design with biological materials moving to

become a key component for both designers and scientists alike. Thus, this paper explores one aspect of the use of biophilic design and its perception; these are defined and briefly summarised here.

Biophilic design is the application of biophilia theory which were introduced by Fromm in 1973 and Wilson (1982) to the built environment by incorporating natural elements in the modern living or non-living space. Nature plays a crucial role in the well-being of the human mind, emotion, and physical well-being (Kellert et al., 2008). Biophilic design has evolved and expanded into practical applications from Biophilia theory. Biodesign (Myers, 2018) is defined as the incorporation of living biological materials or ecosystems that enable the systems designed to be more renewable and sustainable.

Products can create an emotional attachment between the user and the objects. Norman (2004) discusses three levels of emotional response concerning objects, which are; (1) visceral level (2) behavioural level (3) reflective level. These three levels have been used to map product characteristics. Visceral design is the visual appearances that can be interpreted and first response; behavioural design is the effective performance, pleasurable usage of the product and the functionality, and reflective design involves the memories and understandings of the experience of satisfaction after using the product. Generally, emotion can be defined as subjective biological conscious or non-conscious expressions, which involve facial and vocal expressions, physiological symptoms and occur depending on specific events that can be experienced in daily life (Niedenthal et al., 2006). Moreover, Plutchik (2001) and Khalid and Helander (2006) stated that emotions involve human's internal stimulations and occur naturally while influencing the way human beings react, behave and think. This paper extends a study on emotional design and perception survey which were executed to gain feedback on positive and negative emotion towards the Furniture Designs embedded with Living Organisms (FDLOs) (Sayuti et al., 2015 and 2018). The new research, focus more on the application of the biological materials and designs that incorporate biological materials are further identified, where a new survey has been designed for this purpose.

Merleau-Ponty (2004), discussed perception by seeing the connection between the world of perception and the world of science, space, sensory objects, animal life, self and other people experienced, art and philosophy, and the world of classical and modern. Perez Mata et al. (2013, 2015) studied the perception of aesthetics in consumer products and used the categorising developed by Goldman (1995) to categorise the perceptions. Other studies that closely relate to the study of perception in design were conducted by Dunston et al. (2002), DiSalvo et al. (2002), and by Carozza (2016) about Augmented Reality Computer Aided Drawing (AR-CAD), a human-robot interaction was more focused on the initial understanding of facial features images of 48 humanoid robots and the design development of a cybernetic hand (prosthetic hand) devices.

In relation to new creative practices, the application of nature (biophilia) is not novel. Nature has been used directly or indirectly to enhance creativity towards areas such as education (Plambech and Van Den Bosch, 2015; Kiewra and Veselack, 2016), health (McCurdy et al.; 2010) business administration (Ceylan, Dul and Aytac, 2008) and among other fields. However, a deeper understanding of perception of biophilia, and biodesign is needed for these practices to be extended to the creative process of products. This paper found that the natural elements, be it artificial or real materials can elicit a positive or negative perception based on the desirability, practicality, aesthetically pleasing and familiarity in the everyday products.

1.1. Research Aim

The research aims to understand the impact of new emerging creative processes and their outcomes to end users. Specifically, the research investigates the emotional responses and perception of users to biophilic materials. In addition, how these emotional responses and perceptions are affected when the materials are embedded in a product will also be studied. This study will also further clarify the user perception toward biophilia, biophilic design and bio-design.

2. Methodology

This research project was developed in four stages, namely: 1) an initial compilation and classification of biological materials and related products were carried out, 2) the online survey was disseminated to understand the emotional responses and perception of potential consumers towards the biological

elements, 3) the a further development of conceptual model from previous study and tested in the survey, 4) discussion on the early results gathered from the survey. This paper only summarises the main aspects of these four stages.

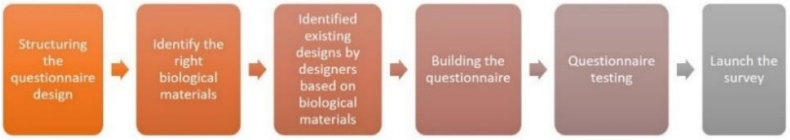

Figure 1: The Experimental Design Phases

A research framework was developed for the research project, Figure 1 shows the main phases in the experimental design. To develop the survey, the researchers first identified types of a living organism/ biological materials that are embedded into existing product designs. These biological materials were then categorised into four categories: 1) *Artificial natural elements* which consist of images of nature such as in photographs, graphics, painting, drawing and others and *artificial plants*, flowers or grass, 2) *Real natural element: plants* such as moss, edible plants, flowers and decorative plants and cacti or succulents, 3) *Real natural element: animals* which involve animals such as fishes, insects and other with due care and 4) *Real natural element: microorganism* such as fungi, algae and beneficial bacteria as can be seen in Figure 2 below.

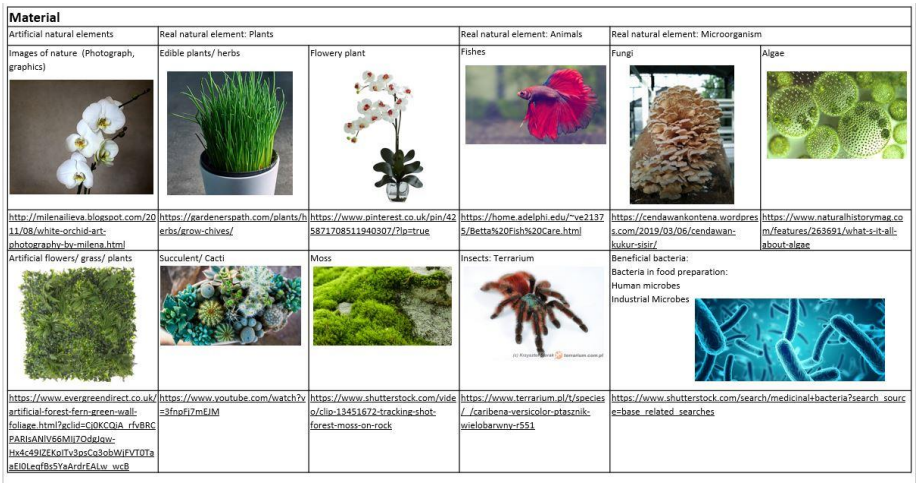

Figure 2: An example of artificial and real biological materials used in the survey

2.1. Questionnaire design

A survey was use to gather the respondent's perceptions and their emotions towards biological elements embedded in designs. The survey gathered data on how people or potential users perceive the biological elements in existing design objects and their emotional response, and how this is affected through the purpose of the object, emotion and the practical use in existing designs. The questionnaire was developed in order to gain feedback from the respondents. This consisted of 6 main sections: *A) Respondent background, B) Artificial and real biological materials, C) Emotional Design: Biological Materials., D) The purpose of biological elements., E). Existing Biophilic Design/ Bio-design*, and *F. Biophilia, biophilic design, bio-inspired design and bio-design*. The questionnaire consisted of visual imagery of biological materials and existing designs by selected designers, thus, no participants were exposed to any biomaterials. Participants were recruited through social media, and the survey was also disseminated through emails. Participation was voluntarily, and a participant could withdraw at any point in the survey. A total of 58 responses were collected and analysed for this paper.

There are at least ten assessment methods that have been developed or used widely in the design fields to measure emotion, which are 1) Likert Scales: which normally use 3-, 5- and 7-points or more (Matell and Jacoby, 1972; Albaum, 1997; Johns, 2010)., 2) semantic differential scale which was developed by

Osgood (1940s to 1950s)., 3) Kansei engineering developed by Nagamachi (1995). 4) Self-Assessment Manikin (SAM) developed by Bradley and Lang (1994) is a method which assesses the pleasure, arousal, and dominance., 5) Positive Affect Negative Affect Schedule (PANAS) was developed by Watson et al. in 1988 to measure a person's positive mood and negative mood., 6) Products as Personalities is a questionnaire for measuring pleasure in products, developed by Jordan in 2000., 7) PrEmo is an abbreviation for Product Emotion Measurement Instrument (PrEmo) was developed by Desmet in 2003 (Desmet, 2003 and 2018; Laurans and Desmet, 2017)., 8) Product Personality Profiling (PPP) was developed by McDonagh et al. (2000)., 9) SEQUAMS: stands for Sensory Quality Assessment Method was developed by Bonapace in 2002., and finally 10) Product Personality Scale was developed by Mugge, Govers, Schoormans (2009). This study adopted PrEmo in order to measure the emotional responses and a likert scale to evaluate perceptions, using the approach of Perez Mata et al. (2013, 2015).

3. Results

3.1. Respondent background

A total of 58 responses were received and analysed for this paper. Background data were collected on *Gender* (70.7% of female, 27.6% of male while 1.7% preferred not to answer), *Age* (ranging from 18-25 with 8.6%, 26 to 30 with 17.2%, 31 to 40 with 43.1% is the highest responses received from, 41 to 50 with 27.6%, while a minimum responses received from 51 to 60 with 1.7% and 61 or older with 1.7%.). The respondents are from a Design and Non-design background with 46.6% and 53.4% respectively. Moreover, almost all participants stated they had access to nature with an overall 91.4%.

3.2. The perception of artificial and real biological materials was analysed

Eleven (11) artificial and real biological materials were identified and used in the questionnaire (see Figure 2). The respondents were asked to use a 7- point Likert Scale to rate the level of desirability (undesirable), practicality (impractical), aesthetically pleasing (unpleasant aesthetically) and the common/ familiarity (uncommon) for the incorporation of artificial and biological materials into everyday products. The results can be seen in Table 1a and b – 4a and b below are the descriptive analysis of the Mean value of the SPSS test. A mean score uses the scale of (-) 3; very, (-)2; quite, (-)1; slightly, 0; neutral, positive integers indicate an overall positive rating (e.g. desirable) and negative a negative rating (e.g. undesirable).

3.2.1 Materials positive or desirable

The desirability of the materials was analysed; the findings showed that 5 materials received a positive level of desirability are moss, edible plants, decorative plants, succulent and cacti and fishes. Three (3) materials received a negative level of desirability (i.e. perceived as undesirable), namely insects, algae, and bacteria. The responses were analysed to understand that there is a difference between designs and non-design background. The artificial plants received a negative response by the design background. Fungi was perceived as neither desirable or undesirable by both groups. Nature images was perceived as neutral by the design group. These results highlighted in grey in Table 1a below. The ANOVA test was applied to compare the significant differences in the Mean on the perception of two groups of respondents (comparing those with a background in design and not design), gender was not used as 70.7% were female for each of these. From Table 1.1b, the images of nature and artificial plants were found to have significantly different responses, i.e. Sig. value (below 0.05) with 0.03 and 0.007 respectively. It was surprising that the bacteria result was not significant given the growing use bacteria within biodesign; it was expected that designers would have a greater level of acceptance.

3.2.2 Materials positive or practicality

The findings showed that 4 materials were perceived to have a positive level of practicality: nature images, edible plants, decorative plants, succulents and cacti. Three (3) materials received negative levels of practicality (i.e. perceived as impractical), are insects, algae and bacteria. Moss and fungi were

perceived as close to neutral (neither practical or impractical) by both groups. While artificial plants and fishes were viewed as close to neutral (neither practical or impractical) by the designers, these results highlighted in grey in Table 2a.

Table 1a: The analysis of Mean value on perception of desirability

Working Background		Nature Images	Artificial plants	Moss	Edible plants	Decorative plants	Succulents and Cacti	Fishes	Insects	Fungi	Algae	Bacteria
Non-design	**Mean**	**1.7097**	**1.0323**	**1.1613**	**1.9355**	**2.1613**	**1.8387**	**1.2581**	**-0.8710**	**0.0968**	**-0.5806**	**-0.6452**
	N	31	31	31	31	31	31	31	31	31	31	31
	Std. Deviation	1.18866	1.51622	1.48541	0.92864	0.86011	1.41649	1.59097	1.92773	1.79545	1.43235	1.92438
Design	**Mean**	**0.8148**	**-0.2963**	**1.5185**	**2.0370**	**1.9259**	**2.0769**	**1.2963**	**-0.4815**	**0.4815**	**-0.1481**	**-0.5926**
	N	27	27	27	27	27	26	27	27	27	27	27
	Std. Deviation	1.84051	2.09054	1.45100	1.05544	1.49167	1.09263	1.61280	1.86816	1.39698	1.61015	1.52566
Total	**Mean**	**1.2931**	**0.4138**	**1.3276**	**1.9828**	**2.0517**	**1.9474**	**1.2759**	**-0.6897**	**0.2759**	**-0.3793**	**-0.6207**
	Std. Deviation	1.57846	1.91058	1.46764	0.98215	1.19094	1.27365	1.58715	1.89373	1.61998	1.51978	1.73537

Table 1b: The ANOVA test for desirability

		Sum of Squares	df	Mean Square	F	Sig.
Images of nature	Between Groups	11.556	1	11.556	4.960	0.030
	Within Groups	130.461	56	2.330		
	Total	142.017	57			
Artificial plants	Between Groups	25.472	1	25.472	7.812	0.007
	Within Groups	182.597	56	3.261		
	Total	208.069	57			

Table 2a: The analysis of Mean value on perception of practicality

Working Background		Nature Images	Artificial plants	Moss	Edible plants	Decorative plants	Succulents and Cacti	Fishes	Insects	Fungi	Algae	Bacteria
Non-design	**Mean**	**1.5161**	**1.2258**	**0.6452**	**1.8710**	**1.7097**	**1.6667**	**1.0323**	**-1.0000**	**0.1613**	**-0.54839**	**-0.7097**
	N	31	31	31	31	31	30	31	31	31	31	31
	Std. Deviation	1.15097	1.23044	1.66430	1.05647	1.16027	1.47001	1.58080	1.77012	1.75303	1.433846	1.86536
Design	**Mean**	**1.1111**	**0.2222**	**0.3704**	**1.3333**	**1.0741**	**1.1481**	**0.1852**	**-0.8889**	**0.1852**	**0.11111**	**-0.2963**
	N	27	27	27	27	27	27	27	27	27	27	27
	Std. Deviation	1.42325	1.67179	1.54791	1.44115	1.66239	1.85439	1.61810	1.62512	1.35978	1.527525	1.46274
Total	**Mean**	**1.3276**	**0.7586**	**0.5172**	**1.6207**	**1.4138**	**1.4211**	**0.6379**	**-0.9483**	**0.1724**	**-0.24138**	**-0.5172**
	Std. Deviation	1.28947	1.52535	1.60308	1.26806	1.43923	1.66848	1.64048	1.69024	1.56875	1.502166	1.68836

Artificial plants and fishes were found to have significantly different responses based upon the background of the participants, i.e. Sig. value (below 0.05) with 0.011 and 0.049 respectively (see Table 2b). Those with design backgrounds perceived the use of artificial plants as neither practical or impractical, whereas the non-design perceived it as practical. Design background also perceived fishes as neither practical or impractical while non-design considered fishes as practical to be embedded in everyday products.

Table 2b: The ANOVA test for practicality

		Sum of Squares	df	Mean Square	F	Sig.
Artificial plants	Between Groups	14.535	1	14.535	6.893	0.011
	Within Groups	118.086	56	2.109		
	Total	132.621	57			
Fishes	Between Groups	10.355	1	10.355	4.054	0.049
	Within Groups	143.042	56	2.554		
	Total	153.397	57			

3.2.3 Materials positive or aesthetically pleasing

From the analysis, 6 materials received a positive level of perception aesthetically pleasing; these were: images of nature, moss, edible plants, decorative plants, succulent and cacti and fishes. Three (3) materials received a negative level of aesthetically pleasing (i.e. perceived as unpleasing aesthetically) are insects, algae and bacteria. Artificial plants and fungi were perceived as close to neutral (neither pleasing aesthetically or unpleasing aesthetically) by both groups. Results are highlighted in grey as in

Table 3a below. There was no significant difference between non-design and design backgrounds for aesthetic in ANOVA test, as all results were more than 0.05.

Table 3a: The analysis of Mean value on perception of aesthetic

Working Background		Nature images	Artificial plants	Moss	Edible plants	Decorative plants	Succulents and Cacti	Fishes	Insects	Fungi	Algae	Bacteria
Non-design	**Mean**	**1.4516**	**0.8710**	**1.2667**	**1.7419**	**2.0645**	**1.9032**	**1.4667**	**-0.8387**	**0.2581**	**-0.2581**	**-0.8387**
	N	31	31	30	31	31	31	30	31	31	31	31
	Std. Deviation	1.20661	1.38424	1.31131	1.09446	0.96386	1.35043	1.47936	1.80918	1.75058	1.54850	1.82751
Design	**Mean**	**1.4444**	**0.2308**	**1.5556**	**2.0000**	**2.0370**	**1.6667**	**1.7407**	**-0.3704**	**0.2963**	**-0.0370**	**-0.7407**
	N	27	26	27	27	27	27	27	27	27	27	27
	Std. Deviation	1.42325	1.81786	1.31071	0.96077	1.28547	1.46760	1.19591	1.66752	1.46274	1.45395	1.22765
Total	**Mean**	**1.4483**	**0.5789**	**1.4035**	**1.8621**	**2.0517**	**1.7931**	**1.5965**	**-0.6207**	**0.2759**	**-0.1552**	**-0.7931**
	Std.Deviation.	1.30010	1.61408	1.30739	1.03362	1.11485	1.39873	1.34774	1.74545	1.60911	1.49621	1.56450

3.2.4 Materials positive or common/ familiarity

The familiarity of the materials was analysed, the findings showed that 3 materials received a positive level of common/familiarity, these were unsurprising: nature images, edible plants and decorative plants. Four (4) materials received a negative level of familiarity (i.e. perceived as uncommon), such as insects, fungi, algae and bacteria. Moss received an uncommon response from the design group in contrast to the non-design, moss was perceived as close to neutral. Artificial plants, succulents and cacti and fishes were viewed as close to neutral (neither common and uncommon) by the designers. These results highlighted in grey as in Table 4a below.

Table 4a: The analysis of Mean value on perception of common/ familiarity

Working Background		Nature images	Artificial plants	Moss	Edible plants	Decorative plants	Succulents and Cacti	Fishes	Insects	Fungi	Algae	Bacteria
Non-design	**Mean**	**1.5161**	**1.2000**	**0.9000**	**1.5806**	**1.8387**	**1.6129**	**1.2258**	**-0.6129**	**-0.1333**	**-0.4516**	**-0.7097**
	N	31	30	30	31	31	31	31	31	30	31	31
	Std. Deviation	1.06053	1.27035	1.32222	1.08855	1.00322	1.14535	1.38347	1.76404	1.50249	1.38657	2.01979
Design	**Mean**	**1.0741**	**0.4815**	**-0.2593**	**1.0370**	**1.3333**	**0.7778**	**0.6667**	**-1.1538**	**-0.6667**	**-0.8889**	**-0.9630**
	N	27	27	27	27	27	27	27	26	27	27	27
	Std. Deviation	1.35663	1.47727	1.58339	1.31505	1.59326	1.62512	1.64083	1.64176	1.44115	1.45002	1.48016
Total	**Mean**	**1.3103**	**0.8596**	**0.3509**	**1.3276**	**1.6034**	**1.2241**	**0.9655**	**-0.8596**	**-0.3860**	**-0.6552**	**-0.8276**
	Std.Deviation.	1.21694	1.40711	1.55255	1.21955	1.32373	1.43934	1.52137	1.71588	1.48510	1.42104	1.77841

Artificial plants, moss and fishes were found to have significantly different responses, i.e. Sig. value (below 0.05) with 0.053, 0004 and 0.026 respectively (please refer Table 4b). These materials are generally known or commonly used or incorporated in any product or urban environment/ living space.

Table 4b: The ANOVA test for familiarity

		Sum of Squares	df	Mean Square	F	Sig.
Artificial plants	Between Groups	7.336	1	7.336	3.897	0.053
	Within Groups	103.541	55	1.883		
	Total	110.877	56			
Moss	Between Groups	19.097	1	19.097	9.064	0.004
	Within Groups	115.885	55	2.107		
	Total	134.982	56			
Succulent and Cacti	Between Groups	10.065	1	10.065	5.218	0.026
	Within Groups	108.022	56	1.929		
	Total	118.086	57			

4. Conclusions, discussion and future research

Emerging creative practices have led to the exploring and usage of biological materials, where these materials provide practical usages and may offer aesthetical value promoting new experience and emotional empathy towards the natural surroundings. The exploratory study was conducted using an online questionnaire to investigate the perception of materials using biodesign or biophilia, and the acceptance of these creative outcomes. The methodology employed to gather data was a custom online survey as the main instrument to disseminate to potential consumers. The finding of these perception,

can be inform the new creative approaches of new designs and materials, enable in data to be collected in larger numbers than other approaches. These studies were used as guidelines Gunn (2002), Roth (2006), Mahon-Haft and Dillman (2010), White and Gatersleben (2011) Hofelich Mohr, Sell and Lindsay and (2016).From the preliminary findings, the following materials: insects, algae and bacteria, were found to have a negative perception for desirability, practicality, aesthetics and familiarity. The background of the participants was also analysed to investigate the difference between a design or non-design background. Some significant differences were found, for example, the desirability of artificial plants were perceived as undesirable, by those with a design background in contrast to those with a non-design background where viewed it as desirable. This research is part of a longer project; future work includes understanding the perception of biological materials when exploring designing products for different purposes in practicality, aesthetic and experience. Furthermore, this project can also be explored further with the use of real living biological materials and embedded it to existing products to investigate the direct experience of living materials.

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